THE INTEGRATION OF ELECTRONIC COMPONENTS INTO MECHANICAL VALVE INTERLOCKING SOLUTIONS IMPROVES EFFICIENCY AND SAFETY

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New developments create intelligence that allows each step within a pigging operating sequence to be monitored, controlled and authorized.

Mechanical interlocking products guarantee strict adherence to procedure and thus avoid human error. They are particularly useful for operations that are generally recognized as highly dangerous, such as pigging. Interlocks are a cost-effective measure that results in extremely high safety levels.

Traditionally however, interlocks function as independent and stand-alone safety systems. But as advanced digital technology now enables us to combine process control and safety instrumented functions within a common automation infrastructure, wouldn't it be better to integrate operator procedures, such as those safeguarded by mechanical interlocks, with the Distributed Control System (DCS) and Safety Instrumented System (SIS) as well?

Separate systems for process control and safety

Historically, separate systems and different technologies provided protection against common-cause failures, in which one problem makes multiple devices or systems fail. Mechanical interlocks perfectly fit within the common philosophy that process control systems and safety systems should always be separated. Once a predefined order of operations has been established and safeguarded by interlocks, there is no other option available than to strictly follow that same predefined sequence of actions. As this sequence can never be altered or overridden, neither manually nor from the DCS, it ensures adherence to the safety procedure.

Combining process control and safety instrumented functions

Within process safety in the traditional sense, add-on components protect personnel from injury and from economic or environmental loss. However, modern safety solutions go far beyond this notion. The deployment of intelligent, integrated safety solutions can save costs, while simultaneously improving process and personnel safety.

Maintaining separate engineering, operation, and maintenance infrastructures for control and safety systems also involves additional costs, and many companies are now considering the merits of a more integrated architecture. More and more, process control and safety instrumented functions are combined within a *common* automation infrastructure for plant control and plant safety.

Different approaches exist when it comes to interfacing a plant's DCS, Programmable Logic Controller (PLC), or relay system with the SIS. The primary function of a DCS or PLC however is always the same; to hold specific process variables to predetermined levels in a dynamic environment. A SIS on the other hand is a static system that takes action when a process is out of control and the control system is unable to operate within safe limits (see Fig. 1).

'Traditional style' plant control

Traditionally, the DCS and SIS were interfaced through a gateway, with each system having its own operator interfaces, engineering workstations, configuration tools, data and event historians, asset management, and network communications (see Fig. 2). In addition to segregation of control and safety equipment, there is separation of responsibilities. The safety engineer is focused on safe operation, whereas the process engineer wants to maximize plant availability and operational profit.

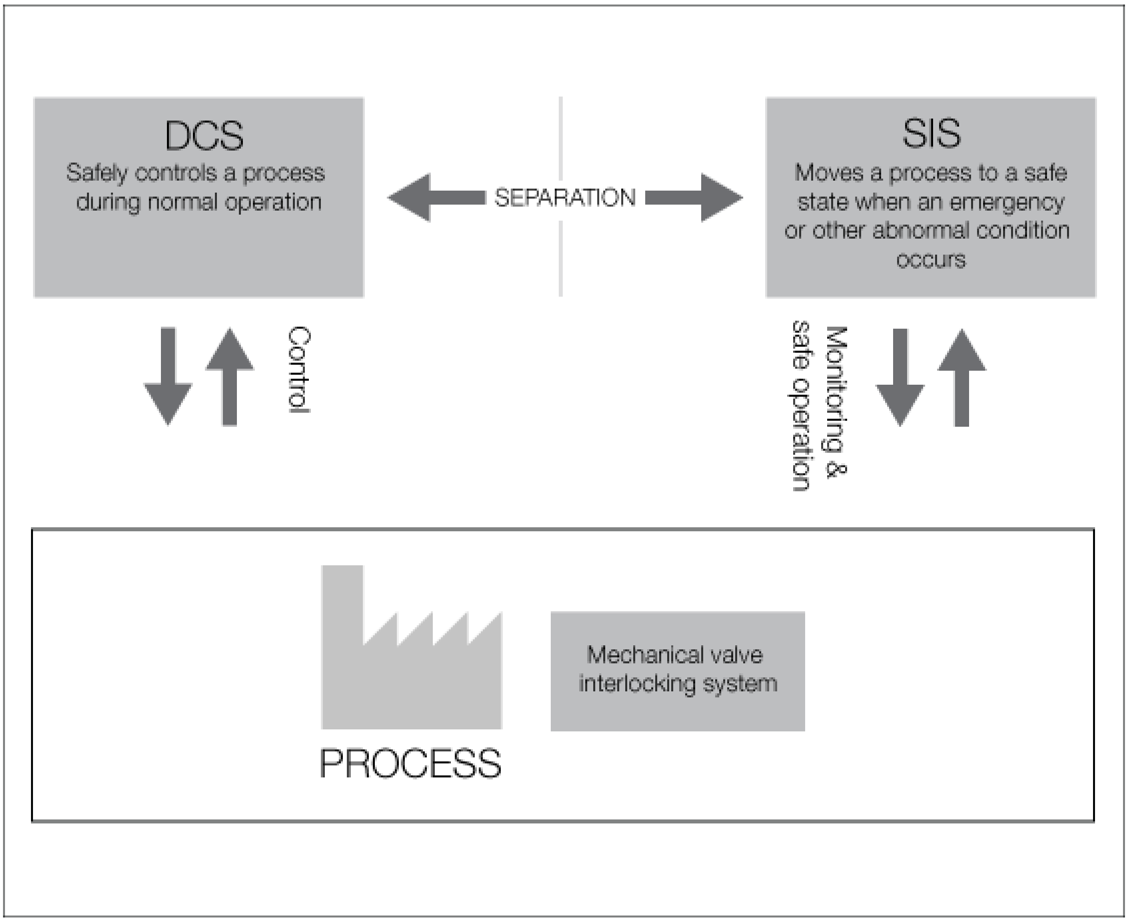

Figure 1: 'Traditional style' plant operation.

'New style' plant control

Because of the costs associated with the separate system approach, many companies started looking for integrated solutions. These solutions have different controllers for DCS and SIS, but they have one engineering, operation and maintenance tool (1). Advanced digital technology has made it possible to combine process control and safety instrumented functions within a *common* automation infrastructure, all while ensuring regulatory compliance (see Figure 2). Industrial facilities can realize significant advantages from seamless - but still secure - integration of plant control and safety systems. Some of the potential benefits include accurate time synchronization, elimination of data mapping duplication, the creation of a common HMI (Human Machine Interface) and reduced operator and maintenance training requirements (2).

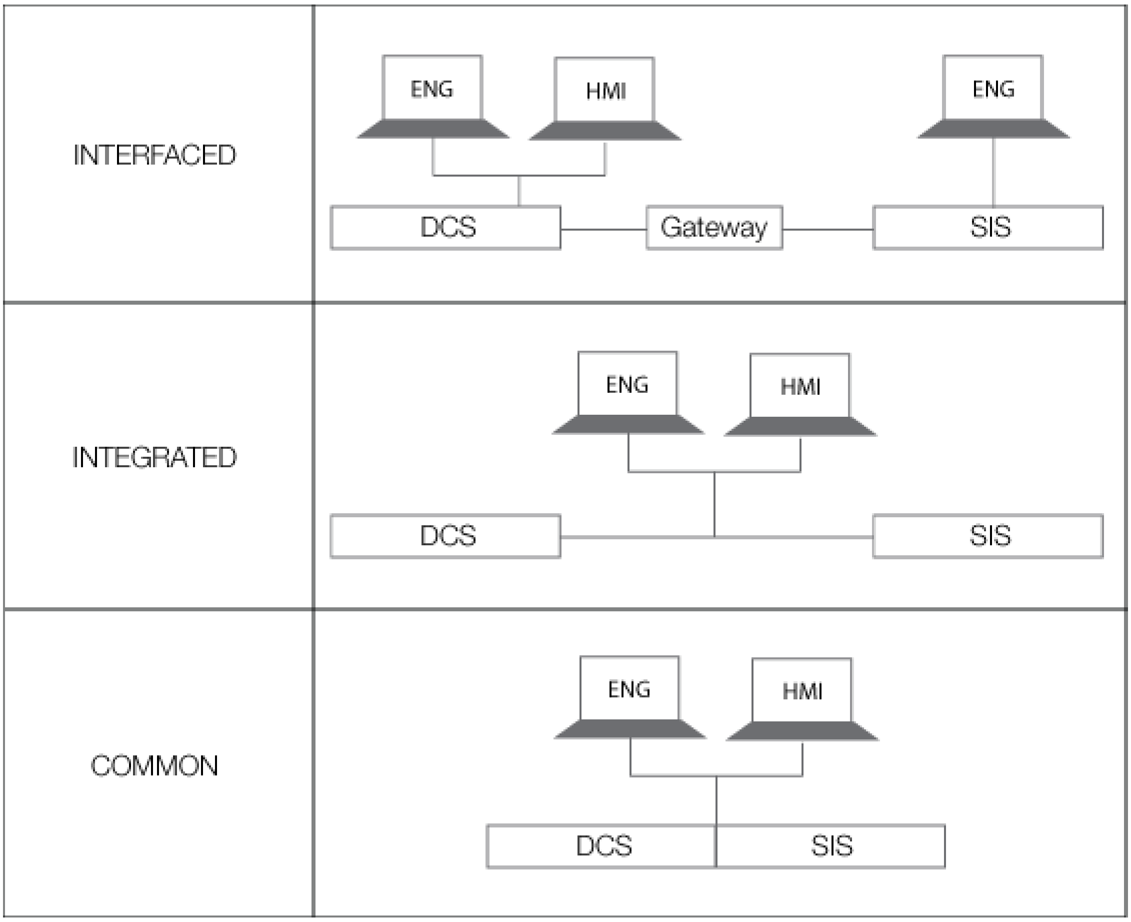

Figure 2: Moving from interfaced' to common' infrastructures (1)

How do mechanical interlocks fit in modern infrastructures for plant control and safety?

Process industries around the world face lots of operational challenges. Ensuring the safety of personnel, equipment, and the environment are priorities for every facility. At the same time, plants must find ways to increase process efficiency and to improve their overall business performance. In order to achieve these goals, common automation infrastructures enable them to ensure safety and at the same time increase process efficiency and thus save costs.

Integration of mechanical interlocks within electronically-powered safety systems

In order to be able to create common automation infrastructures, mechanical interlocks should be connected to the DCS and SIS. However, as many systems for process control and process safety are electronically powered, how can they communicate with manually operated mechanical interlocking systems?

Intelligent interlocking helps to improve overall safety level

New electro-mechanic applications combine electrical and mechanical processes, procedures and feedback. With regard to mechanical interlocks, this has resulted in a new breed of interlocking products that focus on the use of electro-mechanical and PLC-controlled cabinets. These cabinets allow for communicating detailed instructions, monitoring the status of complex procedures and operating part of a sequence from the control room. Moreover, variables such as vessel pressure and H2S levels can be incorporated within safeguarded operating procedures. In all, electro-mechanics enable mechanical interlocking systems to be fully integrated within the context of a common system for control and safety.

Amongst others, 'intelligent interlocking' is based on the idea that ultimately *all* processes within a facility should somehow be interconnected with each other in order to create substantial levels of overall process safety. If companies only focus on highly dangerous processes to be safeguarded and disregard the other less dangerous processes, they will never be able to guarantee SIL 3 and 4 safety levels.

Towards more integrated safety of pigging operations

Especially for pigging operations, integrating the characteristics of purely mechanical interlocks into new electronically powered solutions for control and safety can create a higher overall process safety level.

Intelligent interlocking offers many possibilities, like:

- integration of both mechanical and electronic safety measures into a single, comprehensive system for operating and monitoring complicated valve operating sequences;
- providing live, step by step information, guidance and process overview during the whole procedure;
- enabling remote authorization of processes.

Pigging processes are both high risk and highly related to other processes within the entire plant facility or pipeline infrastructure. A pigging vessel is not an isolated system but is directly linked to the line which is to be pigged. A pigging operation can only be safely initiated when:

- safety conditions are met;
- the line is piggable;
- both launcher and receiver are lined up;
- changing circumstances can be acted upon.

During a pigging operation certain safety conditions are to be met. The vessel pressure should be at a safe level and all dangerous gasses and residue must be removed, prior to opening the hatch. A mechanical interlock system guarantees that all required valve operations are performed, but cannot guarantee results of these operations. E.g. having opened and closed a vent doesn't tell whether the vessel pressure has reached a safe level. Equally, having opened and closed a drain doesn't tell whether all residue has been removed. Intelligent interlocking enables the incorporation of signals from other field devices like pressure or H2S sensors into an interlocking sequence. By doing so the release of certain keys can be conditioned by the right measurements from such field devices. This could mean that the key for opening the vessel closure door will only be released when the pressure level inside the vessel is acceptable and no dangerous gasses or residue is detected inside the vessel.

The line which is to be pigged must be fully accessible. All valves down the line, like remotely operated deep sea valves, should be open for a free passage of the pig. Ideally a pigging operation should not be initiated before all intermediate valves are opened. When using mechanical interlocking, all valves directly mounted to or near the vessel are interconnected, preventing unwanted opening of valves and guaranteeing adherence to safety procedures throughout the pigging process. Intelligent interlocking enables integration of all remote valves in the line. This way it can be prevented that a pigging procedure commences before all intermediate valves are opened. The digital signal about the position of these valves can be used as condition for authorizing of the start of the pigging procedure.

A receiver should be timely prepared to receive the incoming pig. This requires communication between the operators of the launcher and the receiver. When this communications fails, accidents might occur. Ideally a pig cannot be launched before the receiver is ready to receive. When using mechanical interlocks, a launcher and a receiver are secured as standalone systems. With intelligent interlocking, both are coupled into one safety procedure. One might think of a solution where the key for opening the main valve of the launcher is only released after the main valve of the receiver is opened. Another example might be, when a single vessel launches and receives at the same time in a loop. In that case, it should be assured that after launching, the vessel is correctly prepared for receiving as well. An alert could go off in case preparing the vessel for receiving tends to take too long.

Changing circumstances sometimes ask for adjustment or even postponing of an operating procedure. Using only mechanical interlocks provides little or no flexibility to adjust the procedure once started. When a vessels is used for both launching and receiving, 2 different operating sequences apply. With mechanical interlocking, such vessels require multiple sequence control products. Also there's no control over which of the two procedures is started. Intelligent interlocking can combine multiple sequences into one sequence control system and allows for remote authorization of the correct procedure, either launching or receiving.

Sometimes using intelligent pigs requires a different valve operating sequence than a scraper pig, due to their difference in length. For intelligent pigs sometimes the first out of two main valves behind the vessel needs to stay open when opening the hatch, due to the bigger length of that pig. In that case an exception needs to be made to the valve operating sequence, which as a standard require both main valves to be closed. When mechanical interlocks are used, such an exception in the operating sequence is not possible. With intelligent interlocking, alternative sequences can be programmed, allowing for such exceptions to be made.

While preparing for a pig launching procedure, circumstances may change down the line, requiring the postponing of the pigging operation. With mechanical interlocks, a pigging operation cannot be interrupted once started. Intelligent interlocking allows for intermediate alteration or abortion of an initiated operation, thus taking status input from related process systems into account.

An intelligent interlocking system in practice: Nord Stream

Pigging is a notoriously complex process, but one which can be made significantly safer by using mechanical interlocks. A standard, mechanical interlocking system properly guides the operator through the sequence safely. Typically though:

- it does not provide overview (monitoring) of the individual steps of the operating sequence;
- it is not linked to the various pressure and H2S levels throughout the system;
- there is no option to remotely authorize the start of an operating sequence.

Control cabinet integrates all relevant variables

Upon customer request for the Nord Stream project, a specially designed ´control cabinet´ integrates many additional features into one unit:

- position of MOVs condition the release of keys (for manual operated valves) for each stage of the process;
- pressure levels condition the release of keys (for manual operated valves) for each stage of the process;
- releasing the start keys and MOV operation are authorized from the control room;
- position of the valves and pressure are monitored by the control room;
- remote MOV operation controls are included.

Figure 3: Control cabinet and closure, Nord Stream pigging installation

The control cabinet displays the launcher and receiver layout, indicating vessel and pipeline pressure and MOV position at each stage of the sequence.

Pigging process is centrally coordinated

The whole pigging process is coordinated from a Nord Stream location in Switzerland, hundreds of kilometers from the actual pigging stations in Germany and Russia. From the control room the whole pipeline, including the process of launching and receiving, is monitored.

Essential steps within the pigging process are authorized. The control room in Switzerland regulates the release of keys for either launching or receiving in the respective remote locations. This particular intelligent interlocking solution enables a complex pigging operation to be monitored and controlled fully from a central location.

Mechanical interlocks are an integral part of the entire solution and allow the dangerous pigging process to be mechanically safeguarded, but with the added convenience and security of an electronically integrated system.

Figure 4: Control Cabinet, integrating mechanical valve interlocking system with electronic safety measures, Nord Stream pigging installation

Conclusion

Intelligent interlocking combines the reliable characteristics of a mechanical safety solution with dynamic possibilities of electromechanical solutions. By integrating operator procedures with DCS and SIS it allows integration of mechanical safety products with electronic communication, authorization and proofing possibilities. Integrating mechanical interlocking systems within common infrastructures for plant control and plant safety also perfectly fits within the notion that ultimately *all* processes within a facility should somehow be interconnected with each other. This way, substantial levels of process safety can be created, while at the same time realizing efficiency and cost savings.

1) 'Integrated Control + Safety', Siemens, on www.industry.siemens.com
2) 'Integrated DCS and SIS' by J. School en E. de Groot, as published on 'InTech', www.isa.org, the online magazine of ISA (International Society of Automation)